# Identifying Arthritis in Large Dinosaurs


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## Abstract


Osteoarthritis is a debilitating joint disease that, if left untreated, can cause the fusion of separate bones through ossification. This disease, although mostly associated with living organisms such as humans, can be found in many fossil organisms, including dinosaurs. When an organism dies and is fossilized, any bone injuries are preserved as well, and can be examined in great detail. Learning about injuries in extinct organisms can help understand those found in modern ones. In the summer of 2016 I interned at the Judith River Dinosaur Institute conducting my own independent research, which has extended into my senior year of college. I am looking at pathologies seen in large dinosaurs, specifically evidence of arthritis.

My project focuses on examining an undescribed *Camarasaurus* specimen from the Jurassic Morrison Formation in Montana. A *Camarasaurus* is sauropod; the family of dinosaurs that contain the longest and heaviest Dinosauria. This specimen shows evidence of arthritis in caudal (tail) vertebrae 3 and 4, a pathology has potentially caused uncharacterized ossification as well as deterioration and fusion of the vertebral disc. Bone spurs are only present on the ossified vertebrae and not on any other excavated bones. Based on physical appearance, evidence of bone spurs between vertebrae, deterioration of the cartilaginous disc and location within the organism, we believe it to be a severe form of osteoarthritis.

We also hypothesize that this injury was caused by some kind of blunt trauma to the spine. The location of the caudal vertebrae is incredibly close to the hip, and there is no evidence of predation on the bones. Due to the location, it may have been a mating injury caused by a bull male *Camarasaurus* mounting a female, suggesting our specimen is female. After blunt force trauma, the injury would have caused aggravation of the area as the animal swung its tail back and forth, and over the course of many years, a bony ossification from osteoarthritis would have stiffened the joint.

Research has previously been done on dinosaur pathologies, including arthritis (1, 9). Common forms of pathologies in dinosaurs include Diffuse Idiopathic Skeletal Hyperostosis (DISH), arthritis, cancerous growth, ossification without arthritis, sepsis and ankylosing spondylitis (1, 3, 4, 5, 6). Sauropod pathologies have mostly focused around evidence for DISH and only some evidence of arthritis (2, 5). Based on the ossification pattern, the vertebrae I am working with most closely resembles osteoarthritis or ankylosing spondylitis (1, 2). Unlike DISH, my specimen does not have a "candle wax" appearance normally associated with DISH, and the level of ossification found exceeds what would be expected with cancerous growths (4, 5, 6). Accurate identification of the pathology in my specimen will be a great addition of a rare pathology to the low number of specimens that show such traumatic injuries.

To help distinguish the pathology in my specimen as well as fill in the gaps of known fossil pathologies, we performed additional assays. First, we performed a CT scan on the fossil and took 3-D scans, which make it easier to see the density as well as visualize the bone without the possibility of breaking it. At this moment, the pathology seems to be ossification caused by osteoarthritis. Currently, to verify our hypothesis, our samples are being prepared for histological analysis which will allow us to see the inner structures of this bone. This analysis will allow us to eliminate several possible types of injuries, and help support or reject the hypothesis that it is osteoarthritis. These histologic slides can also be compared to those of extant organisms with similar injuries, helping us to understand how these injuries develop over long periods of time in an organism's life. Taken together, our data will help us not only determine what this animal suffered from, but also help us understand how an untreated injury in large animals can develop over time.


## Introduction

***Camarasaurus*:**

- A mid-sized herbivorous sauropod dinosaur between 15 and 23 m long.
- These fossils were excavated from the Morrison Formation in Montana.
- The bones are dated to 155 million years old, during the Jurassic Period.

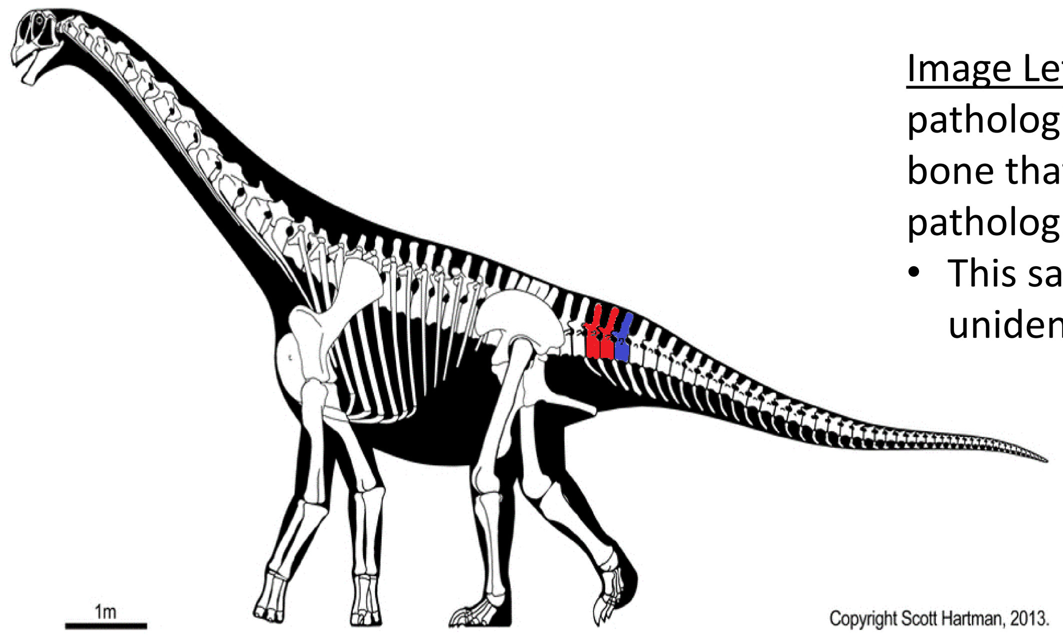


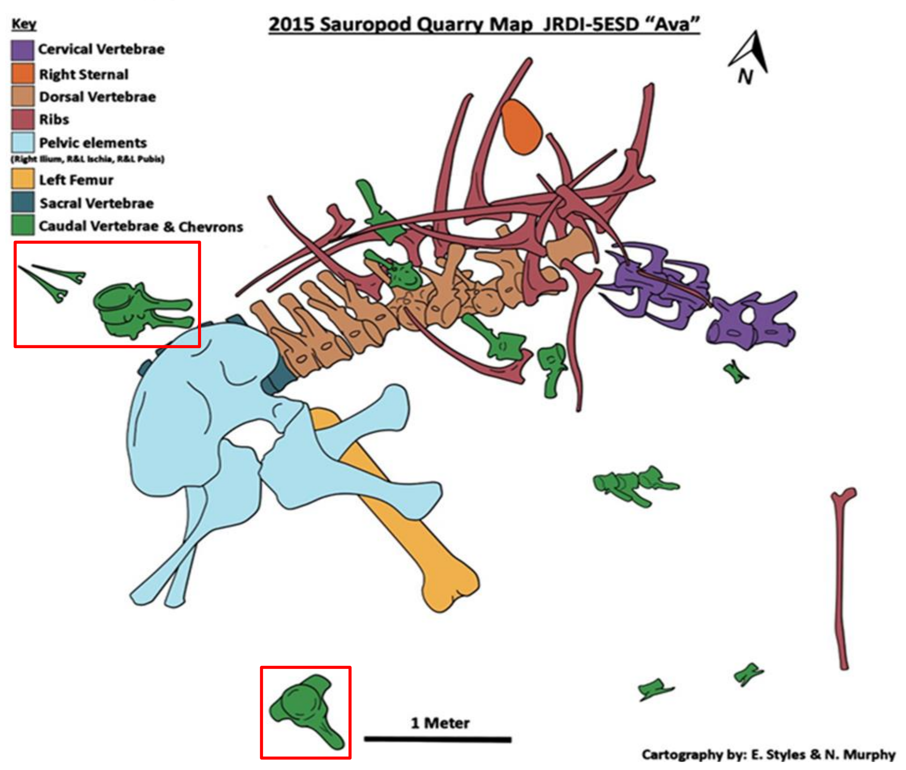



Image Left: In this animal, red indicates pathologic bone, blue indicates normal bone that was examined alongside pathologic bone.

- This sauropod dinosaur specimen is an unidentified species, not yet named.

**Caudal Vertebrae with Pathology:**

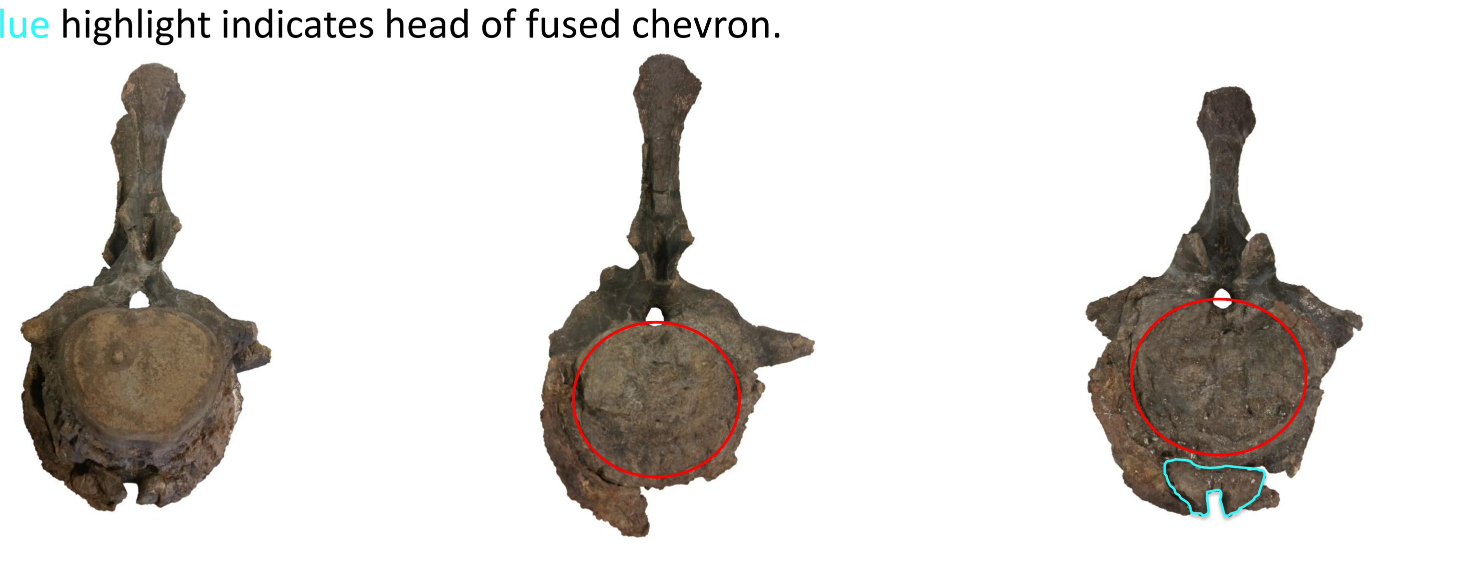
- CV3 and CV4 affected.
- CV5 shows no signs of ossification or arthritis.
- Ossification has fused CV3 and CV4.
- Chevron bones (required for muscle attachment) are fused to the vertebrae.




Green bones in red boxes are fossils examined in this study

**Pathologic Bones:**

- Left to Right: CV4 on top of CV3 (caudal side), CV3 (caudal side), CV4 (cranial side).
- Red circles indicate normal intervertebral disc size.
- Blue highlight indicates head of fused chevron.



## Goal

To determine and understand the type of pathology that this *Camarasaurus* has, and relate it to extant animals.

## Arthritis

**Definition:**

- A disease that effects the joints in the body.
- Can be associated with stiffness and pain of the affected joint.
- There are many different types, two of which seem the most similar to this pathology:
  - Osteoarthritis
  - Ankylosing Spondylitis

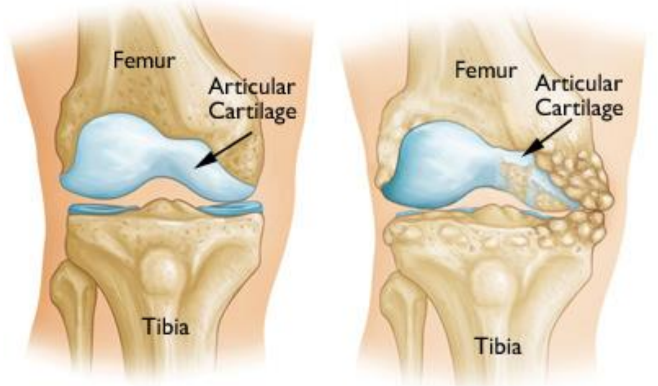



Image from: Sydney Knee Specialists

**Homology in Extant Animals:**

- Osteoarthritis and other forms of arthritis are not exclusive to *Camarasaurus.*
- Arthritis is even present in other species of dinosaurs, such as theropods, other species of sauropods and hadrosaurs.
- The disease is most commonly found in humans and large animals.
- By looking at pathologies in the past, we can better understand pathologies seen today and avoid allowing such injuries or diseases to reach this extent, especially in humans.
  - Only bone is preserved in fossils, while in humans you have both soft and hard tissues, often making it complex to differentiate severe osteoarthritis from other, less common, types of arthritis.
  - The opposite is also true, with only bone, we cannot properly identify if an infection was present, or to what extent the cartilage was damaged.

## Materials and Methods

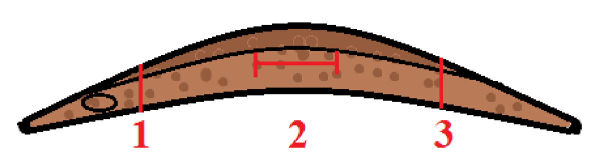
**Fossil Preparation:**

1. The ossified and fused bones were separated in the lab, but later CT scanned together in original fused position.
2. The fused caudal vertebrae 3 and 4 were cleaned with a sand blaster and dental drills.
3. Next we treated the bones with a liquid plastic sealant for protection.
4. Black epoxy/putty was used to fill in gaps to stabilize the fossils where bone was not recovered.

**CT Scanning:** performed in Billings Clinic by Jason Orendorff RT.

**Histologic Slides:**

- A partial fragment of the ossification was sent to Wagner Petrographic for thin sectioning to view the bone through microscopy.
- The fragment, pictured right, was cut in three sections to better visualize the ossification. There was a bony protuberance on the left side of the fragment, pictures as a black circle.




Cranial view (towards the front of the animal)

- Slides were viewed under a Nikon Eclipse E800 microscope with a DS-Ri1 camera.

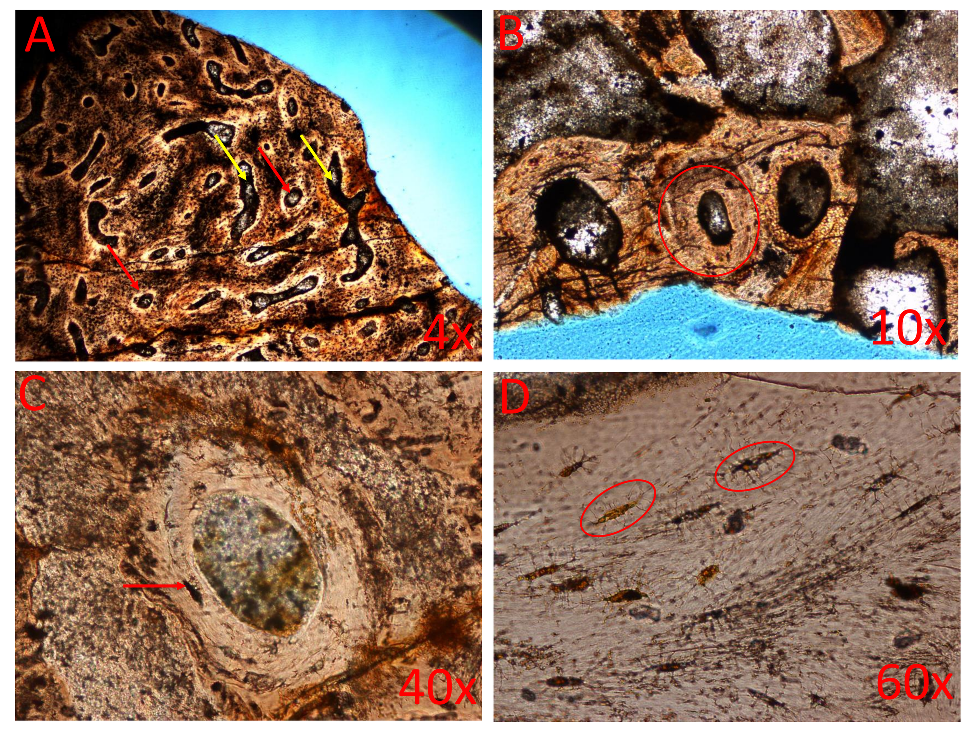
## Results

**CT Scans:**

- Left: X-ray imaging of CV3 and CV4 placed on top of each other.
- Right: 3-D imaging of CV3 and CV4 placed on top of each other.
- Both images are lateral views with bones oriented cranial to caudal.
- Scans revealed that bone is too dense for proper imaging, but 3D scans provided a clear and easy way to view the ossified pathology.

**Histological Slides:**

A. Visible osteons (red arrows) as well as disorganization of bone (yellow arrows), consistent with an infection or disease.
B. Clearly visible osteons (red circle)with Haversian canals.
C. Osteon further magnified with osteocytes (red arrow) visible.
D. Osteocytes visible with no visible damage (red circles).




| Features of Fossil | Osteoarthritis | Ankylosing Spondylitis | Septic Arthritis | DISH | Osteomyelitis | Neoplasm | Chronic Infection |
|---|---|---|---|---|---|---|---|
| Ossification | x | x | | x | | x | x |
| Fusion of Bones | x | x | | | | | x |
| Infection | x | ? | x | | x | x | x |
| Localized | x | | x | x | x | x | x |
| Found in/around Joint | x | x | x | | x | x | x |

**Identification of Features in Pathology:**

- The pathology seems to be most consistent with osteoarthritis and or chronic infection.
- Infection (chronic or single event) may have led to osteoarthritis.

## Conclusions

- Ossification is most likely due to osteoarthritis which may have been caused by a preliminary infection, or blunt trauma.
- Osteoarthritis resulted from degradation of the cartilaginous articular disc over time.

## Future Directions

- Use an electron scanning microscope to further view microstructures within the bone.
- Continue to compare this pathology to that of other sauropods and extant animals.
- Excavate and evaluate additional fossils excavated of this specimen. Fossils of interest include: CV1, CV2 and the hip structure.


### Acknowledgements

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